REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
14-09-2017	Final Report	28-Apr-2016 - 27-Apr-2017

4. TITLE AND SUBTITLE
Final Report: Equipment for the Transient Capture of Chaotic Microwave Signals

5a. CONTRACT NUMBER
W911NF-16-1-0291

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611103

6. AUTHORS

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
North Carolina State University
2701 Sullivan Drive
Admin Srvcs III, Box 7514
Raleigh, NC 27695 -7514

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
68431-EL-RIP.1

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Michael Steer
UU	UU	UU	UU		19b. TELEPHONE NUMBER 919-515-5191

RPPR Final Report
as of 06-Oct-2017

Agency Code:

Proposal Number: 68431ELRIP **Agreement Number: W911NF-16-1-0291**
INVESTIGATOR(S):

Name: David Ricketts
Email: dricket@ncsu.edu
Phone Number: 9195155191
Principal: N

Name: Michael Steer mbs@ncsu.e
Email: mbs@ncsu.edu
Phone Number: 9195155191
Principal: Y

Organization: **North Carolina State University**
Address: 2701 Sullivan Drive, Raleigh, NC 276957514
Country: USA
DUNS Number: 042092122 EIN: 566000756

Report Date: 27-Jul-2017 Date Received: 14-Sep-2017
Final Report for Period Beginning 28-Apr-2016 and Ending 27-Apr-2017
Title: Equipment for the Transient Capture of Chaotic Microwave Signals
Begin Performance Period: 28-Apr-2016 **End Performance Period:** 27-Apr-2017
Report Term: 0-Other

Submitted By: Michael Steer Email: mbs@ncsu.edu
Phone: (919) 515-5191

STEM Degrees: 0 **STEM Participants:** 0

Major Goals: The goal of the project was to acquire equipment suitable for the capture of transient chaotic microwave signals. Chaos either superimposed on microwave signals or a microwave signal that is inherently chaotic is in some cases an important component complicating the capture of microwave signals. Chaos appears to lead to phase noise on microwave oscillators, and appears to lead to spurious tones on a vibrating antenna and these are not captured using a spectrum analyzer. A high-speed sampling oscilloscope is required to capture actual chaotic signals. Long capture times are needed and over-sampling by a factor of 8 is required so that the effective number of bits can be increased from the actual bit resolution of 8 can be extended to 12 effective bits after over-sampling.

Accomplishments: aADPO77002SX Tektronix Oscilloscope was purchased for the measurement and analysis of high-frequency signal and their characteristics. The unit has a sampling rates of 200 GS/s and large memory (1 GB) enabling real time acquisition of transient signals with analog bandwidths up to 70 GHz for one channel, and 30 GHz for two channels..

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI

RPPR Final Report
as of 06-Oct-2017

Participant: Michael Bernard Steer
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Co PD/PI
Participant: David Ricketts
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Equipment for the Transient Capture of Chaotic Microwave Signals

In this project a DPO77002SX Tektronix Oscilloscope was purchased for the measurement and analysis of high-frequency signal and their characteristics. Key to the acquisition and analysis of high-frequency signals, in particular chaotic and stochastic signals, is the ability to accurately capture the time-voltage series as it occurs. Oversampling scopes use a periodic sampler to create an effective larger bandwidth, which masks any deviation from an ideal periodic signal as occurs in chaotic and stochastic signals. With the aid of extremely high-sampling rates (200 GS/s) and large memory (1 GB), an accurate measurement of time-voltage series can be captured and analyzed.

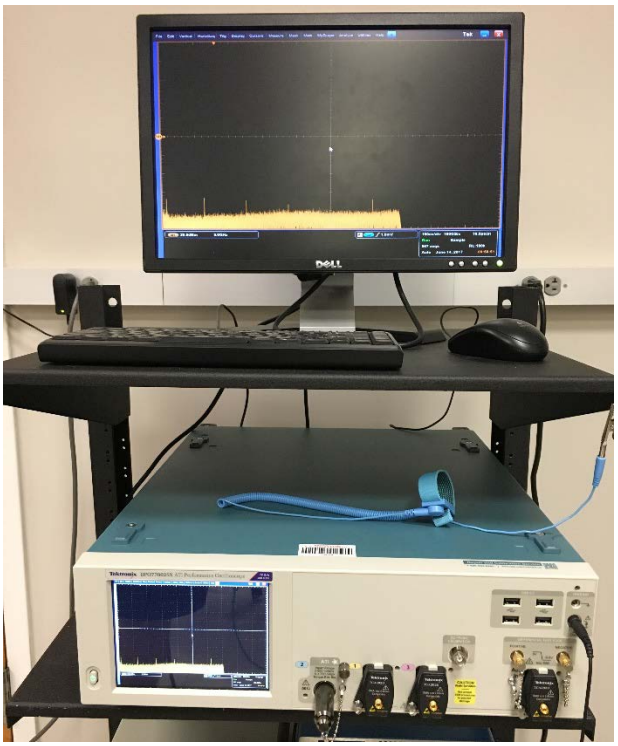
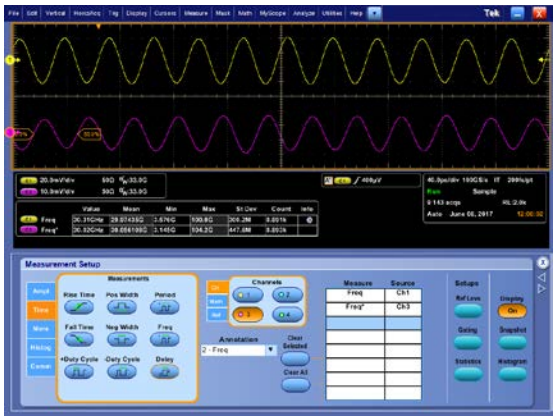
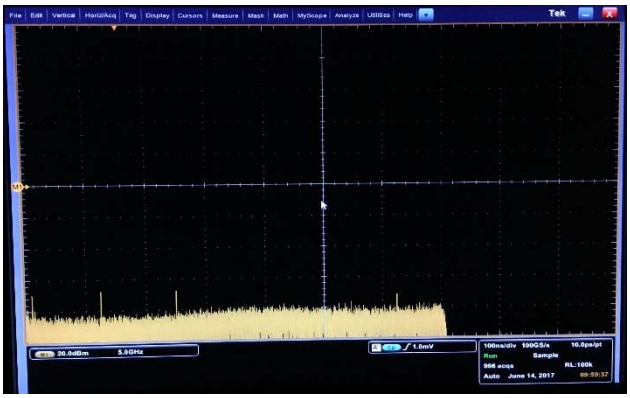


Figure 1: DPO77002SX Oscilloscope. Sampling body and display output. Two 33 GHz sampling heads on left. 70 GHz sampling head on right.

The DPO77002SX is a 2+1 channel oscilloscope sampling at 200 GS/s using Tektronix patented time-interleaving technique. It has an input referred noise level of 5 mV. Channels 1 and 2 divide the sampler between two signals in order to provide two 33 GHz BW measurements with signal measurements up to 6 V on a standard RF 50 Ohm connection. This enables direct comparison of two uncorrelated signals in real time. Below is an example of measurement of two 30 GHz signals. Th instrument is able to capture both at full bandwidth and display any non-coherence between them.



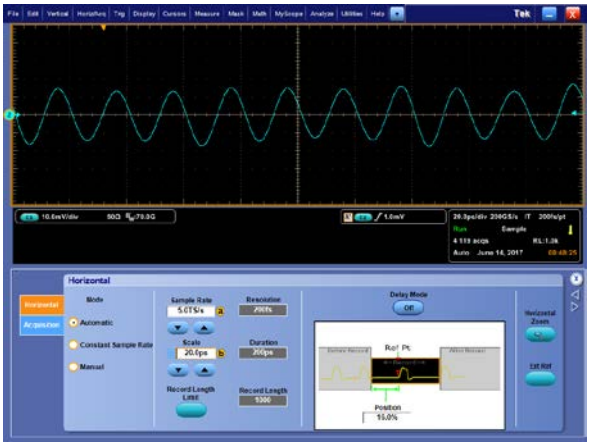
(a)



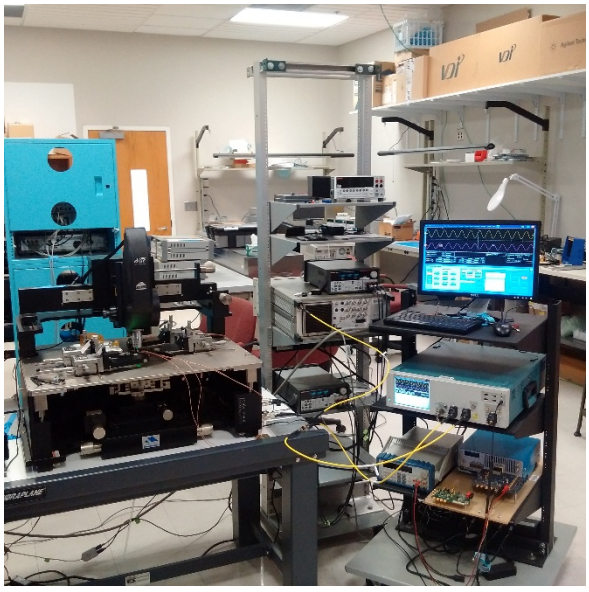
(b)

Figure 2: (a) Measurement of two 30 GHz signals. Instrument is capable of capturing non-coherence of signals. (b) Measurement of the noise floor of the 33 GHz channel.

Highest speed measurements are performed with the 200 GS/s, 70 GHz BW measurement head. The precision head achieves high-speed, partly through reduced amplitude (300mV), however is able to achieve 4.5 bits of resolution at 70 Ghz. Key to the impact of this instrument is the integration with mm-wave and high-speed circuits. The instrument has been installed to connect directly to our mm-wave probe station, where measurements of 3-300 Ghz can be made. The instrument will be used to measure the ultra-wide band signals down converted from 220 and 300 GHz radios, the output of 40 GS/s track-and-hold circuits in advanced SiGe as well as time-voltage series of noisy and chaotic oscillators and devices. The figure below shows a measurement of a 50 GHs signal with the high-speed sampling head and the unit with the mm-wave measurement system at NCSU.



(a)



(b)

Figure 3: (a) Measurement of 50 GHz signal by high-speed sampling head. (b) Integration of instrument with NCSU mm-wave systems.